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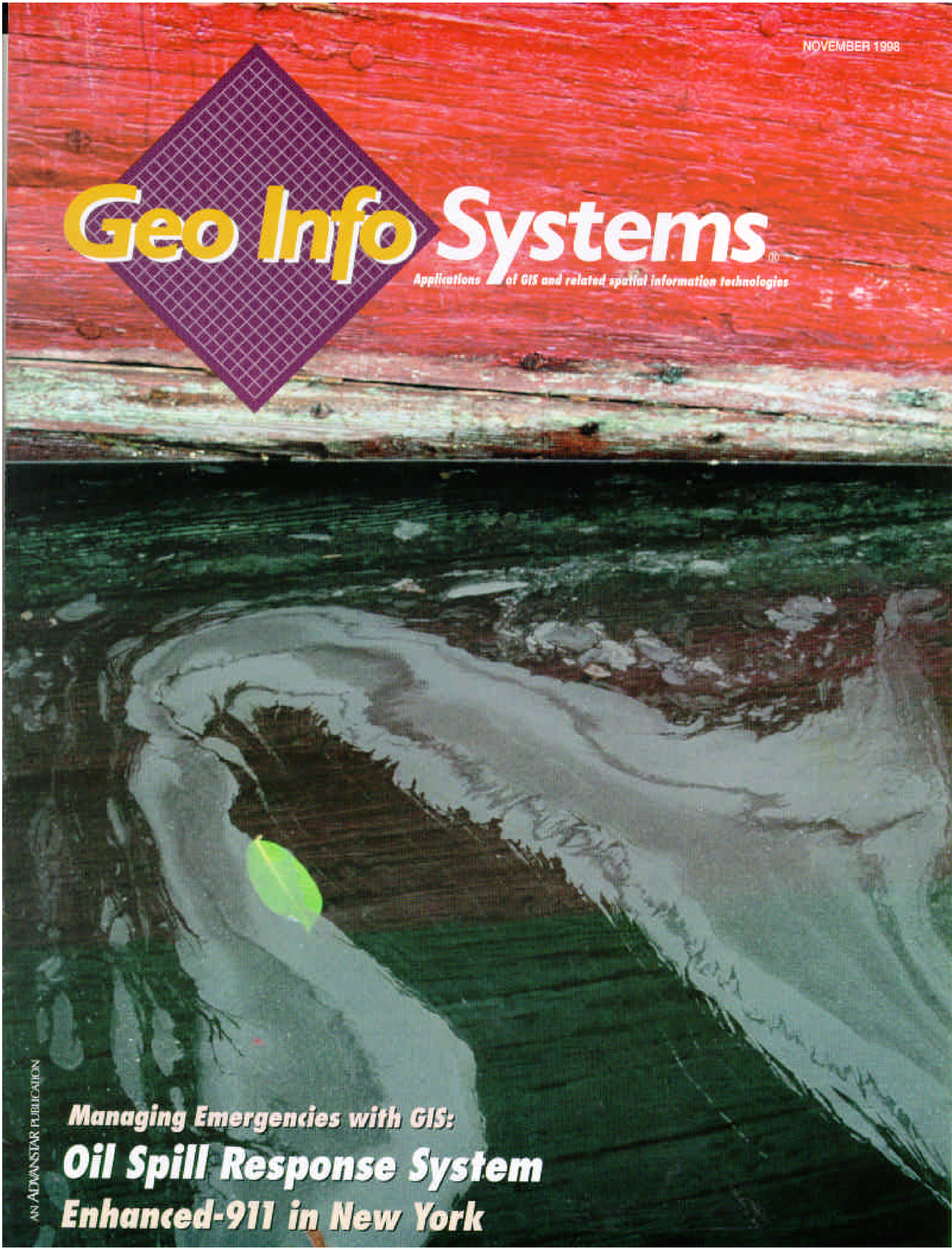
Geo Info Systems

Applications of GIS and related spatial information technologies



Managing Emergencies with GIS:

Oil Spill Response System

Enhanced-911 in New York

AN ADVANSTAR PUBLICATION

New Technologies

The Florida Department of Environmental Protection began developing a GIS-based Marine Spill Analysis System in 1991. The success of the prototype in dealing with the 1993 Tampa Bay oil spill led to the system's statewide expansion. Government and non-government agencies recently teamed up to assess using new technologies with the system to support oil spill response and cleanup.

for Emergency Response

Testing a Prototype System in Florida

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On August 10, 1993, the outbound freighter Balsa 37 collided with two inbound tugs, the *Seafarer* and the *Fred Bouchard*, near the mouth of Florida's Tampa Bay. *Seafarer's* barge burst into flames, burning for more than 14 hours before firefighters on local government and Coast Guard vessels managed to control the blaze. Leaking chemicals such as Jet A fuel and Number Six fuel oil, the collision created a slick l7 miles long and 2.5 miles wide. The outgoing tide carried the spill out to sea. For the first few days it appeared that Tampa Bay had dodged the bullet. Then, a change in the direction of the prevailing wind drove the spill shoreward.

Research scientists from the Florida Marine Research Institute (FMRI, Saint Petersburg) - within the Florida Department of Environmental Protection (FDEP) - flew over the oil spill in a helicopter provided by FDEP's Marine Patrol. These scientists used Global Positioning System (GPS) receivers to determine the spill's perimeter and track its movement for eight days. On returning to FMRI, the scientists transferred the GPS files to a GIS to produce maps of the spill trajectory.

Small scale (1:60,000) maps were most appropriate while the slick was moving offshore, but as the oil neared land and washed ashore, the type and scale of mapping changed. Maps having Environmental Sensitivity Index (ESI) shoreline rankings and additional annotation were needed to coordinate the 800 volunteers and contractors who assembled to assist in the cleanup efforts. The prototype Marine Spill Analysis System (MSAS), containing ESI maps for the Florida Keys, was quickly altered to support spill response in the Tampa Bay area. Various databases, images, and charts from the National Oceanic and Atmospheric Administration (NOAA) were scanned, integrated, and rectified to create ESI maps showing the locations of biological and cultural resources in the predicted path of the spill. These were hand-delivered to the U.S. Coast Guard command center so that responding agencies could work off of the same information to formulate response plans.

More than 330,000 gallons of oil were carried out to sea and then driven by the wind toward shore (Friel et al. 1993). Oil coated sand beaches at Fort DeSoto Park and Saint Petersburg Beach, and mangroves, seagrasses, and oyster beds with in Boca Ciega Bay. FMRI used the prototype MSAS to create more than 1,000 maps showing the location of spill boundaries and resources at risk. The command center, media, and field workers used these maps. MSAS proved to be an effective tool for portraying oil spill conditions, helping decision-makers prioritize response and cleanup efforts.

TEAM WORK IS A MUST

Responding to emergencies such as oil spills or hurricanes in Florida requires coordination among various government and non-government participants. With oil spills, for example, a unified command is established between federal participants from the U.S. Coast Guard, NOAA Hazardous Materials Response and Assessment (HAZMAT), state representatives from FDEP, and participants representing those responsible for the oil spill.

In the case of hurricanes or forest fires, the Department of Community Affairs—Division of Emergency Management (DCA—DEM) takes the lead. Other groups that may become involved include the Florida National Guard (FNG), county or municipal officials including local police and firefighters, and private contractors. Generally, DCA—DEM establishes a command center where decision makers deploy staff, volunteers, and equipment to deal with the problem. Reliable data concerning field conditions are a requirement for proper response. Field personnel must rapidly gather these data and communicate them to the command center.

Portable, lightweight field equipment for data gathering, global positioning, and communications is a necessity for any type of emergency. To determine whether certain new technologies could be integrated to support emergency response, FMRI and NOAA Coastal Services Center (CSC, Charleston, South Carolina) evaluated a prototype emergency response system (ERS) involving cutting-edge GIS, computer, and communications technologies (Rubec et al. 1998). This study conducted in Fort DeSoto Park in Pinellas County, Florida, from August 17—20, 1998 was funded through a grant from the NOAA High Performance Computing and Communications Program to the CSC.

MSAS HISTORY

In 1991, FMRI began developing the Marine Spill Analysis System (MSAS) to support oil spill response by the department’s Bureau of Emergency Response (BER). The initial prototype, developed by ESRI (Redlands, California) ran ARC/INFO software on UNIX workstations. After the Tampa Bay oil spill, FDEP decided that MSAS should be expanded to support oil spill response statewide. The Tampa Bay experience, although successful, indicated the need for a more user-friendly, low-cost, PC-compatible sys tem that could be used by BER spill responders who were not GIS specialists.

Between 1994 and 1996, the institute sponsored the creation of 292 environmental sensitivity index (ESI) maps (see Figure 1) – 1:24,000 scale, 7.5-minute U.S. Geological Survey quadrangles by Research Planning Incorporated (RPI, Columbia, South Carolina). RPI produces ESI Atlases and is the main contractor assisting NOAA HAZMAT. Several other contracts from FMRI gave ESRI the opportunity to convert ARC/INFO vector coverages to ArcView 2.1 shapefile formats during 1996. A review by BER staff led to further revisions of the MSAS, including the creation of new Avenue programs by ESRI customized for oil spill response (Norris et al., in press).

BER staff uses the MSAS statewide. The sys tem currently runs ArcView 3.0 and Microsoft Windows 95 software on Pentium-based laptop computers. The ESI maps classify the sensitivity of shoreline types to oiling conditions and pro vide locations of coastal habitats (for mangrove and seagrass, for example), biological (such as bird rookeries and sea turtle nesting sites), and human-use (marinas and water-intake sites, for example) resources-at-risk coastwide in Florida (Friel et al. 1997).

When a large oil spill occurs, FMRI GIS staff take the MSAS and computer equipment to a command center established near the spill site. The MSAS enables rapid creation of customized maps by combining various ES! shoreline, habitat type, and resources-at-risk coverages. MSAS can also create reports summarizing the resources affected within designated areas. For this study, we wanted to determine whether MSAS components could also support field data collection.

Wearable equipment. Because most laptop and pen-based computers weighing more than five pounds can be cumbersome in the field, we beta tested the ViA II PC (ViA, Northfield, Minnesota) wearable computer in our search for a more lightweight – in this case, approximately 14 ounces – solution. We also tested a beta version of Direct GPS (Trimble Navigation, Sunnyvale, California) software for ArcView 3.0 obtained with an AgGPS 122 (Trimble) unit. This 1.5-pound differential GPS (DGPS) receiver works with a combined GPS—radio-beacon antenna to receive coordinates from satellites and beacon signals from the U.S. Coast Guard. The DGPS equipment in a backpack can operate "stand alone" linked to the wearable computer through a serial port. As part of the evaluation of a wireless local area network (WLAN), we also tested Trimble Pathfinder 8-channel GPS PC cards with two of the wearable computers. The GPS PC card and an antenna mounted on a hard hat eliminates the need for users to wear backpacks.

COLLECTING OIL SPILL DATA

During most emergencies, field data are gathered using paper forms. A common problem encountered is the delay associated with gathering, transporting, and manipulating the data before they become available to decision-makers. The oil spill community uses Shoreline Cleanup Assessment Team (SCAT) forms. For our study, we used ShoreClean version 2.1 (Environmental Software Solutions [ES2J, Montreal, Quebec, Canada) SCAT software for digital data collection to sup port oil spill response and cleanup. This software consists of both a field data gathering module (ShoreClean-SCAT) and a command center module having decision-tree programs that provide decision makers with advice concerning cleanup options.

Figure 1 (top). This sample Environmental Sensitivity Index map depicts shoreline habitats, as well as biological- and human-use resources at risk from oilspills in Tampa Bay.

Bottom: This field worker is using a pen tablet and stylus to draw a polygon representing a shoreline segment.

An October 1996 study by FMRI and ES2 evaluating the use of ShoreClean version 1.1 and the MSAS at Fort DeSoto Park indicated the need to link the two together so that users in the field could relate ShoreClean data to shoreline segments associated with ES! maps (Rubec et al. 1996). For our current study, we tested a beta version of ShoreClean-SCAT linked to ArcView 3.0 installed on two wearable computers. Field personnel documented hypothetical oiling conditions in relation to shoreline habitats and tested Shore-Clean's ability to document the extent of a spill by filling in digital forms to number shoreline segments. This process was accomplished on the ViA II's pen tablet using pull-down menus and through the use of a digital keyboard activated by a pen stylus.

Personnel then used raster-based images for the Fort DeSoto area, obtained from a digital

Figure 2. A shoreline segment drawn over the digital orthophoto quadrangle backdrop of shoreline habitat conditions near Fort DeSoto pier.

Figure 3. This field worker is wearing a Global Positioning System (GPS) unit in a backpack linked to both a differential GPS antenna and a wearable computer.

Figure 4. Fieldworkers also used lightweight equipment including a video camera and GPS antenna mounted on a hard hat linked to a wearable computer with PC cards installed in a belt pack.

orthoquad quarter quad (DOQQ) installed in ArcView. This allowed DOQQ images to be displayed on the pen tablet associated with the wear able computer. Shoreline habitats such as salt marsh, mangrove, and sand beach were visible on the color pen tablet. Field staff tested the new ability to draw shoreline segments over DOQQ backdrops using the pen stylus, which allowed them to annotate maps in ArcView. This process enables users to delineate shoreline segments and create Shoreline Oiling Sketch (SOS) maps (see Figure 2).

FMRI also hired ES2 to facilitate directly importing DGPS readings into ShoreClean. Previously, users manually entered the latitude and longitude data obtained from a GPS unit into the software's data entry screen. Our goal was to automatically log DGPS signals into the dBase III database supporting both ShoreClean and ArcView. Field personnel used the GPS and DGPS equipment previously discussed to record the locations of pits dug along the shoreline to assess the hypothetical penetration of oil into the substrate (see Figure 3).

WIRELESS NETWORK

We tested the Raytheon WLAN using high-gain omnidirectional and unidirectional antennas linked to a special Raytheon Raylink PC card installed in the Access Point. The card allows 2.4 gigaHertz communication from laptop or pen-based computers at rates as fast as two megabits per second. This extended the range of the WLAN as much as three miles along the beach.

During the ERS evaluation, we tested the WLAN by linking several wearable computers in two-way communication with a Dell 233 mega-Hertz notebook computer over a Microsoft Windows NT network. An audio headset with speaker and microphone and a Kodak DVC 300 digital video camera mounted on a hard hat (see Figure 4) were tested for two-way voice transmission of voice and image data between the wearable computers and the notebook computer. The Pathfinder GPS PC card was installed in the wearable computer along with a Raylink WLAN PC card. We tested the wireless transmission of still images and video captured by the digital camera, which was connected through a universal serial bus to the wearable computer.

Vocaltec's Internet Phone version 5.0 provided two-way, voice-activated communication with the wearable-computer user by way of TCP/IP protocol. Microsoft's NETBUI networking protocol was used for drive mapping so that shapefiles and still images could be transferred from the wear able to the notebook and vice-versa. The digital video camera software included still picture and movie-format recorder applications. Field personnel used these applications to capture images and transfer them to the notebook computer, which acted as a base station.

The notebook computer operator used PC Anywhere 8.0 software (Symantec, Leiden, The Netherlands) to view and control the wireless user's wearable computer in real time. The operator used the software to activate the wearable-computer user's Trimble GPS software to display latitude, longitude, altitude, time, the number of satellites being accessed, and signal strength. Running this software on the user's screen apparently taxed the wearable computer's

processing power, which caused the Internet Phone's normally smooth speech communications to become choppy. We worked around this by keeping the GPS application in the background except when needed.

Field staff gathered data along the beach using two wearable computers. ArcView GIS shape-files, other dBase files plus the voice, still images, and video were transmitted from the wearable computers to the notebook computer over the WLAN. The operator of the notebook computer monitored data collection on the wear able computers and instructed field workers to carry out various procedures, such as navigating through ShoreClean menus, opening or closing various software, and transmitting files or images. These software tests demonstrated that a network operator, situated at a central point on the shore line, could coordinate field operations over the network.

SATELLITE COMMUNICATIONS

In the event of a hurricane, it is likely that ground-based communications systems such as telephone lines, radio, or microwave towers will be damaged. Consequently, mobile equipment using satellite communications is necessary.

Satellite telephones. Quickly deployable satellite telephones often serve as the first means of communication from a disaster site. During the ERS evaluation, we tested STl5l (American Mobile Satellite Corporation [AMSC]) 25-pound and ST251 [AMSC] 8-pound satellite telephones. Both units facilitate two-way digital communication of voice or computer data between the field and a command center anywhere in North America. Radio transmission from the units is also possible. ShoreClean data files were transmitted back through the AMSC-l L-band satellite to a command center set up at FMRI using the PC Any where software. The evaluation showed the utility of satellite

Figure 5. This television communications truck, supplied by the Florida National Guard, was used to transmit imagery to the command center.

telephones for oil spill response. For example, spill responders who have used cellular telephones at recent spills in California and Texas found that the cellular network became overload ed. Oil spills can occur at many isolated locations outside the areas covered by cellular telephone networks. Satellite telephones have an advantage because even isolated areas of North America are accessible through the AMSC network.

Very small aperture terminal (VSAT) facilities. Statewide, DCA—DEM maintains 130 stationary VSAT facilities that can uplink and downlink voice and computer data using asynchronous analog communications. For the ERS evaluation, DCA—DEM provided two mobile VSAT trailers equipped with gasoline-powered generators. The first trailer uplinked images and ShoreClean data gathered on the beach using the WLAN. The second VSAT trailer at FMRI downlinked the data from a Ku-band satellite.

Television. An asynchronous, broadband satellite-television truck (Figure 5) enabled the transmission of video and still images from the field to FMRI. The Florida National Guard unit associated with the Emergency Response and Management Program at St. Petersburg Junior College provided this truck. The analog images were uplinked to a Telstar 4 Ku-band satellite and downlinked to a 1.2-meter satellite dish on the roof of FMRI.

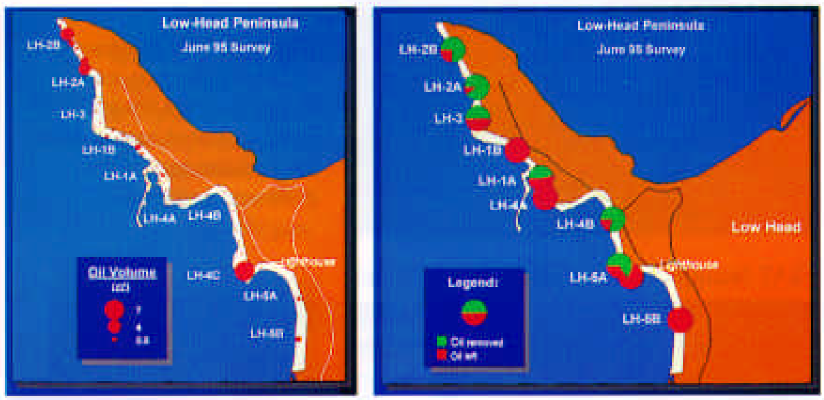
Data integration in the command center. Prior

to the ERS evaluations, GIS staff established a command center in a conference room at FMRI. We only had a half-hour window to transmit images through the FNG television system. Still images and video files were received by way of the rooftop television dish. Image files and ShoreClean data files were received from the DCA-DEM VSAT system.

MAPS FOR DECISION MAKERS

FMRI GIS personnel at the command center analyzed and transformed ShoreClean data into an array of representations – maps, summary reports, and lists of cleanup recommendations –targeted to the various types of decision makers. Normally, decision makers include teams of people responsible for planning, operations, and high-level strategic decisions.

The data analysis transformed data into useful information. The SCAT information manager, who was responsible for data maintenance and



Figures 6a and Ib. Composite maps depicting the status of estimated oil volume (6a, above left) and shoreline cleanup operations (6b, above right), created to support decision makers in the command center.

the timely provision of information to decision makers, manipulated the data. FMRI GIS staff ran ShoreClean software and MSAS on computers connected over a LAN. They used the report-making capability of ShoreClean to determine the best shoreline cleanup options.

The ShoreClean dedicated software linked to the MSAS can facilitate decision making in the command center by visualizing the data on maps. FMRI GIS staff used ShoreClean 2.1 software to merge various segments and create composite maps in ArcView (Lamarche et al. 1996). Users can depict the extent and degree of oiled habitat, the current status of cleanup operations, and the deployment of personnel and equipment on composite maps (see Figures 7a and 7b).

CONCLUSIONS

The ERS's main limitation was transmitting data over analog satellite communication systems. We anticipate a shift to broadband digital communications using satellites operating with the Kaband in the next two to three years. The Internet-based software tested on the WLAN will then support cost-effective, two-way communication of voice, computer, and video data between the field and a command center.

Using the system being developed, command center staff should monitor emergency situations more efficiently and deploy personnel and equipment rapidly. Although more work is needed, the hardware and software tested worked individually and as part of an integrated ERS. Lessons learned and the experience of having worked together make everyone involved better prepared for emergency response in Florida.

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